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Lab. Project 4759-14

From: Commander, New York Naval Shipyard
To: Chief, Bureau of Ships (Code 634C1)

13 JUN 1963

Subj: Cavitation erosion resistance of coatings applied to glass-reinforced epoxy substrates. Project SF 013-13-01, Task 906, Bureau of Ships Identification No. 14-906-1

Ref: (a) BUSHIPS ltr F 013-13-01 Ser 634C1-402 of 7 May 1962
(b) J. Z. Lichtman, D. H. Kallas, C. K. Chatten and E. P. Cochran, Jr., Cavitation Erosion of Structural Materials and Coatings. Corrosion, Vol 17, Oct 1961, 497t-505t
(c) D. H. Kallas, J. Z. Lichtman and C. K. Chatten, Cavitation Erosion Resistant Coatings. Seventh JANAF Conference on Elastomers R & D Oct 1962, ONR Document ONR-13 pp 422-442, 1962
(d) MATLAB NAVSHIPYDNYK Lab. Project 4759-14, Progress Report 7 of 18 Apr 1961
(e) MATLAB NAVSHIPYDNYK Lab. Project 4759-14, Progress Report 10 of 15 Feb 1962
(f) MATLAB NAVSHIPYDNYK Lab. Project 4759-14, Progress Report 9 of 18 Sep 1961
(g) COMNAVSHIPYDNYK ltr 949:JZL:nt, Lab. Project 4759-14 of 20 Apr 1962

Encl: (1) Photo L18196-527 - Cavitation Erosion Damage of Uncoated and Coated Glass-Reinforced Epoxy Disks
(2) Photo L18196-528 - Cavitation Erosion Damage of Coated Glass-Reinforced Epoxy Disks
(3) Photo L19527-15 - Cavitation Erosion Damage of Coated Glass-Reinforced Epoxy Disks
(4) Table 1 - Description of Disk Specimens
(5) Table 2 - Relative Cavitation Erosion Resistance of Coatings and Uncoated Plastics

## 1. INTRODUCTION

a. The Material Laboratory has been investigating the cavitation erosion resistance of structural materials and coatings, and developing cavitation erosion resistant coatings as authorized in reference (a). As part of this program, the erosion resistance of a series of coatings, as applied to a low erosion-resistant glass reinforced epoxy structural material (GRP), has been investigated and is described herein. The GRP used in the investigation has been proposed by Kaman Aircraft Corporation, for use in fabrication of variable pitch ships' propellers.

b. The elastomeric coating systems (polyurethane and neoprene) were found to be more erosion resistant than the resinous binder coatings (polyurethane and polyester) although the elastomeric coating thicknesses (10 mils) were not adequate to achieve optimum erosion resistance as indicated by previous investigations, references (b) and (c), in which coating thicknesses of 30-40 mils were used. The adhesive strength of the coating system was also found to be highly significant in determining the performance of the coating. Low adhesive strength was a major cause of the failure of the polysulfide rubber coating.

2. DESCRIPTION

a. Test coatings and disks. Twenty-two glass-reinforced plastic test disks, fabricated in accordance with the drawing shown in reference (b), Figure 4, were submitted to the Laboratory by the Kaman Aircraft Corporation. Twenty of the test disks had been coated by Kaman Aircraft Corporation with materials to be tested for cavitation erosion resistance properties. Two of the disks were left uncoated to be used as experimental controls. Each of the coated disks had a single material applied to both of its sides of the eleven different coating materials applied; nine were applied to duplicate disks. Two coating systems were applied to only one disk each. Table 1 lists the coating materials on the disks as supplied to the Material Laboratory. With the exception of the neoprene-coated disks, no duplicate coated disks were tested in the rotating disk apparatus.

b. Coating thickness and adhesive strength. Coating thickness measurements were made by examining cross-sections of the test disks with a calibrated optical magnifier (7X). Peel adhesion tests were made to determine the adhesion strength of the coating material to the disk substrate where it was possible to peel the test material from the substrate. This could be done only with the non-brittle elastomeric materials. The thickness measurements and adhesion data are listed in Table 1.

c. Cavitation erosion exposure. The cavitation source holes of the disks were reamed to remove any coating material from the cylindrical surfaces of the holes, and also to return them to their desired 3/8 inch diameter dimensions. Variation of cavitation sources among the different disks were thus minimized. The specimens were run in the cavitation erosion rotating-disk machine, as described in references (b) and (d). Tests were run with a shaft speed of 3200 rpm, 15 psig water pressure in the test chamber, and fresh tap water as the test liquid. Periodic observations were made of the occurrence of damage of the test disks and coatings. The duration of the tests was dependent upon the cavitation erosion resistance of the coating materials at the 150 fps tangential

velocity locations of the test disks. The erosion resistance of the material was determined by the test time required to perforate the coating material to the substrate of the disk at these locations. With but three exceptions, the tests were concluded 1-2/3 hours after observing initial coating perforation, in order to allow the slower occurring erosion damage at the 125 fps locations to progress to perceptable levels. Of the three exceptions, two were the uncoated control disks which were tested until the GRP material at the 150 fps locations had been perforated. The third disk, coated with glass-flake resin, experienced coating perforation at the 125 fps location after only 1/4 hour of testing.

d. Erosion resistance evaluation. The erosion resistance of the coatings was evaluated on the basis of the test time required to perforate the coatings to the substrate at the 150 fps cavitation source hole (total test time minus 1-2/3 hours). Test time was significant to plus or minus fifteen minutes. Therefore, no distinction as to erosion resistance properties of materials made when test times differed by fifteen minutes or less.

3. RESULTS

a. Erosion behavior at 150 fps. Table 2 groups the coatings into three categories, according to relative cavitation erosion resistance (test time to perforate at 150 fps). Materials are listed in alphabetical order within each category. Category A includes the coating material which showed the longest test time and highest erosion resistance in the tests. Category B lists materials showing intermediate erosion resistance. Category C lists materials showing low cavitation erosion resistance.

b. Erosion behavior at 125 fps. It is to be noted that optimum erosion resistance (zero erosion) at 125 fps after periods of 7 hours or more total test time was shown by the Adiprene L-100 coating (XH 438) and the neoprene coating (N). All the other coatings and bare GRP disks showed erosion damage at 125 fps in less than 5-2/3 hours of total test time.

c. The appearance of the uncoated disks and coatings after cavitation exposure is shown in enclosures (1), (2) and (3). These photos show the hole sources at 100, 125 and 150 fps velocity locations and the coating materials downstream of the sources.

4. ANALYSIS AND CONCLUSION

a. Table 2 groups the materials tested on the basis of their cavitation erosion resistance. With the exception of the polysulfide rubber and the Adiprene L-100 prime (XH 398) materials, all the low resistant materials were resinous, non-elastomers, while the materials possessing high or moderate erosion resistance were elastomeric.

b. These results are consistant with previous studies, references (b), (c), (d), (e) and (f) which have shown that certain elastomeric materials are better able to resist cavitation erosion than are non-elastomeric materials, including even high strength metals and plastics. All the resinous non-elastomeric materials exhibited low cavitation erosion resistance. The only material which were cavitation erosion resistant or showed promise of being so were the elastomeric materials, Adiprene L-100 (XH 438) and 3M (XS 1221346) polyurethanes, and neoprene. It is believed that the elastomeric materials applied to the test disks by Kaman Aircraft Corporation would have shown higher cavitation erosion resistance if they had been applied in greater thicknesses, as described in reference (g). This thickness factor is considered to be the main reason for the superior cavitation erosion resistance performance of the seven mil thick Adiprene L-100 (XH 438) as compared to that of the four mil Adiprene L-100 prime (XH 398) although both materials are of the same polymer type.

c. The only elastomeric material which showed poor performance was the polysulfide rubber coating. The coating failed because of the combination of low adhesion strength to the substrate, insufficient thickness, and low tear strength.

5. SUMMARY

a. The Material Laboratory has conducted a study to determine the suitability of materials for application as cavitation erosion resistant coatings of GRP materials. The results show that some elastomeric coatings have superior cavitation erosion resistance properties to those of the non-elastomeric resinous coatings.

b. The test results are consistent with prior material studies conducted by the Material Laboratory, as reported in references (b), (c), (d), (e) and (f). These indicate that certain elastomeric materials are better able to resist cavitation erosion damage than are most non-elastomeric materials.

c. The full effectiveness of the cavitation erosion resistance of the elastomeric materials tested could not be determined because of the low adhesive strength and/or low thickness of the coatings.

d. It is understood that recent service trials of glass-reinforced propellers have shown failures due to structural defects. For this reason the Laboratory will discontinue evaluation of cavitation erosion resistant coatings for glass reinforced propellers unless otherwise directed by the Bureau

D. H. Kallas

D. H. KALLAS
By direction

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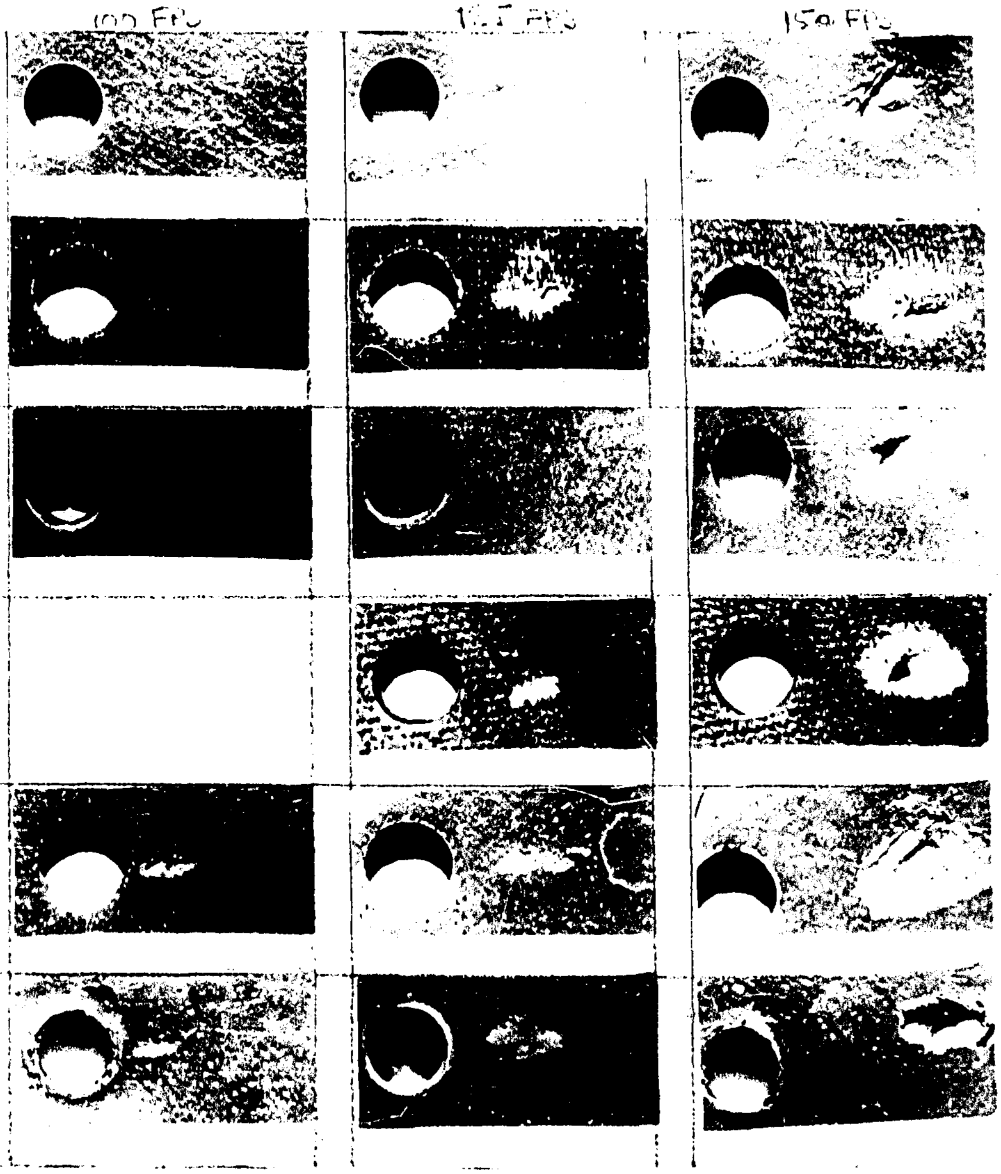
CAVITATION EROSION MEASUREMENTS OF LAMAN DISKS

100 FPS | [illegible] FPS | 150 FPS



CONTROL #4
COATING - NONE
FRESH WATER 1 3/4 hrs.

CONTROL #6
COATING - NONE
FRESH WATER 1 1/4 hrs.

XH 438
COATING - ADIPRENE L -100
FRESH WATER 15 hrs.

XH 398
COATING - ADIPRENE L-100 PRIME
FRESH WATER 2 hrs.

XS 1221346
COATING - 3M POLYURETHANE
FRESH WATER 4 hrs.

N
COATING - NEOPRENE
FRESH WATER 5 1/3 hrs.

**MATERIAL LABORATORY** **LAB. PROJECT** 4759-14

**Enclosure (1) - Cavitation Erosion Damge of Uncoated and Coated Glass-Reinforced Epoxy Disks**

**PHOTO** L 18196-527

CAVITATION EROSION MEASUREMENTS OF KAMAN DISKS

C
COATING - CERMET
FRESH WATER 2 hrs.

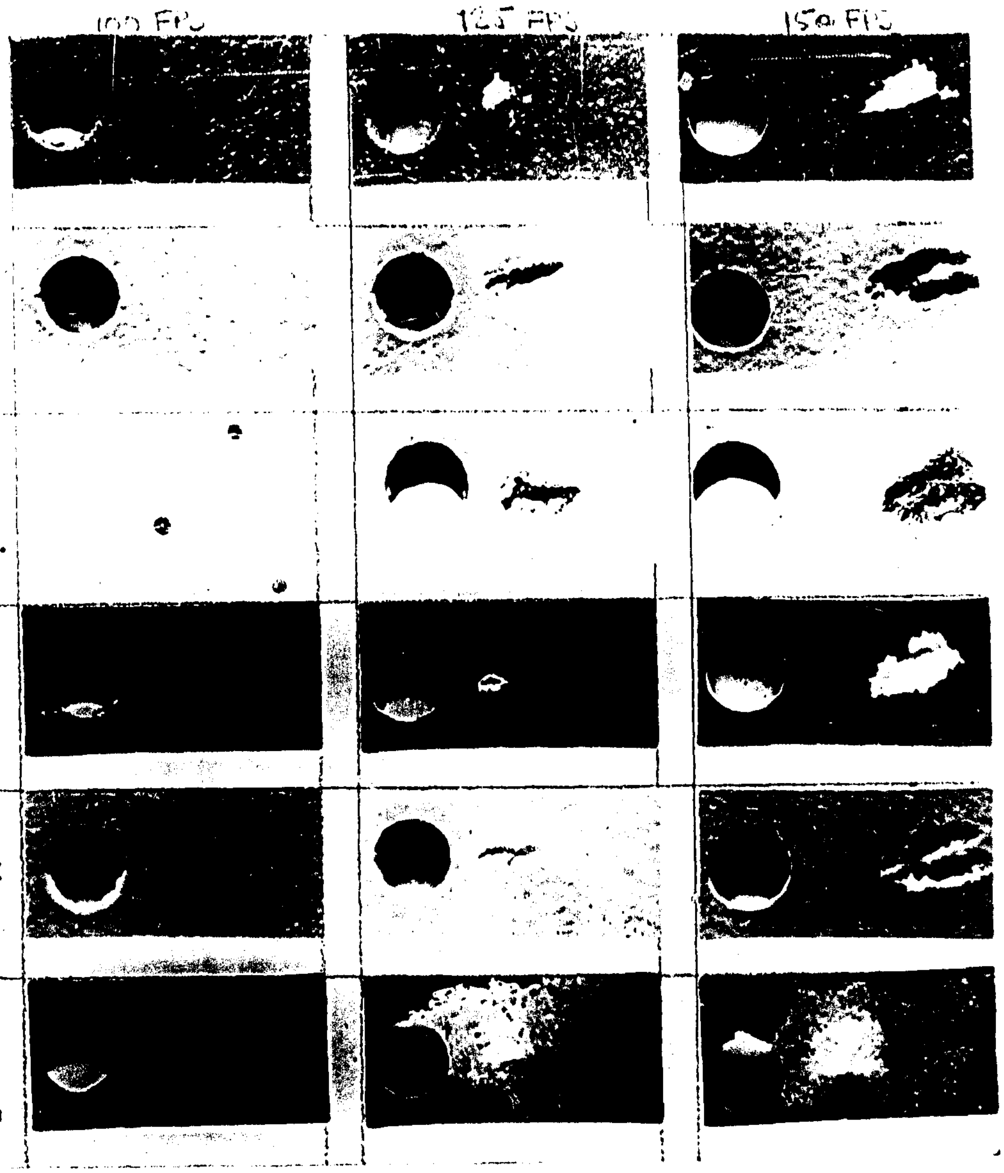
M
COATING - METALOX
FRESH WATER 2 hrs.

4x41
COATING - 4x41 INTERMEDIATE
FRESH WATER 2 1/3 hrs.

4x41C
COATING - 4x41 INTERMEDIATE & CERMET
FRESH WATER 2 hrs.

4x41M
COATING - 4x41 INTERMEDIATE & METALOX
FRESH WATER 2 hrs.

NO DESIGNATION
COATING - POLYSULFIDE RUBBER
FRESH WATER 3 1/2 hrs




MATERIAL LABORATORY

LAB. PROJECT 4759-14

Enclosure (2) - Cavitation Erosion Damage of Coated Glass-Reinforced Epoxy Disks

PHOTO L 18196-528

| | 100 FPS | 125 FPS | 150 FPS |
|---|---|---|---|
| NO DESIGNATION<br>COATING - POLYESTER GLASS FLAKE<br>FRESHWATER 1/4 hrs. |  |  |  |
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MATERIAL LABORATORY LAB. PROJECT 4759-14

Enclosure (3) - Cavitation Erosion Damage of Coated Glass-Reinforced Epoxy Disks

TABLE 1

DESCRIPTION OF DISK SPECIMENS

| Test Material | No. of Disks | Test Material Thickness in. (2) | Adhesion Strength ppi |
|---|---|---|---|
| Glass reinforced plastic (3) | 1 | 0.115 | - |
| Glass reinforced plastic (3) | 1 | 0.124 | - |
| Adiprene L-100 (XH 438) | 1 | 0.007 | - |
| Adiprene L-100 prime (XH 398) | 1 | 0.004 | - |
| 3M Polyurethane (XS 1821346) | 2 | 0.006 | - |
| Neoprene (1) | 2 | 0.011 | 8.8 |
| Cermet | 2 | 0.003 | - |
| Metalox | 2 | 0.004 | - |
| 4 x 41 Intermediate | 2 | 0.005 | - |
| 4 x 41 Intermediate & Cermet | 2 | 0.004 | - |
| 4 x 41 Intermediate & Metalox | 2 | 0.006 | - |
| Polysulfide Rubber (1) | 2 | 0.005 | 3.1 |
| Owens Corning glass flake (M-100) Altac 380 polyester resin | 2 | 0.010 - 0.096 | - |

Note: (1) Not identified.
(2) Thickness of uncoated disk or thickness of coating.
(3) Uncoated disks.

Enclosure (4)

TABLE 2

RELATIVE CAVITATION EROSION RESISTANCE OF COATINGS AND UNCOATED PLASTICS

| Material | Cavitation Test Time, hr |
|---|---|
| A. Highest Erosion Resistance | |
| Adiprene L-100 (XH 438) | 15 |
| B. Median Erosion Reistance | |
| 3M Polyurethane | 4 |
| Neoprene | 5-1/3 |
| C. Lowest Erosion Resistance | |
| Control #4 | 1-3/4 |
| Control #6 | 1-1/4 |
| Adiprene L-100 Prime (XH 398) | 2 |
| C - Cermet | 2 |
| M - Metalox | 2 |
| 4 x 41 | 2-1/3 |
| 4 x 41C | 2 |
| 4 x 41M | 2 |
| Polysulfide Rubber | 3-1/2 |
| Glass flake resin | 1/4 |

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